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Intracorporeal Lithotripsy With the Alexandrite Laser

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Background and Objective: **The objective of this study was to evaluate clinical use of an Alexandrite laser lithotripter for intracorporeal lithotripsy of urinary calculi.**
Study Design/Materials and Methods: **We prospectively evaluated a flash lamp pumped, Q-switched Alexandrite solid-state laser for use in conjunction with ureteroscopy (30 cases) or percutaneous nephrolithotripsy (2 cases). The laser operates at a wavelength of 755 nm in a pulsed mode with pulses of 150–800 ns duration at energy settings of 30–80 mJ.**
Results: **The fragmentation rate with the Alexandrite laser alone was 50% (16/32). Failure of the laser was due to equipment malfunction or technical problems in 11 cases and inability to fragment the stone in 5. All cases of failed Alexandrite laser lithotripsy were successfully salvaged with alternative modalities of endoscopic stone destruction and removal. One intraoperative complication, a ureteral perforation, occurred; however, no long-term sequelae related to laser use was documented.**
Conclusion: **Clinical results with the Alexandrite laser appear to be inferior to those reported with alternative laser systems and other forms of intracorporeal lithotripsy. Whereas some of the inadequacies we have noted may be addressed in the future by modifications in the unit and delivery systems, we would not recommend this device for intracorporeal lithotripsy of urinary calculi in its current form. Lasers Surg. Med. 20:433–436, 1997.**

Key words: endoscopic lithotripsy; laser lithotripsy; renal calculi

INTRODUCTION

The advent and development of extracorporeal shock wave lithotripsy (ESWL) (Dornier Medical Systems, Kennesaw, GA) have revolutionized the treatment of most renal and ureteral calculi. Some patients remain, however, who are managed most effectively by endoscopic means. In this context percutaneous and ureteroscopic extractions of calculi have become well established procedures in Urology. Even with the most ingenious endoscopic equipment and techniques, the diameter of a nephrostomy tract working sheath or the ureteral orifice through which a calculus must be removed presents a physical limitation to simple mechanical extraction. A variety of intracorporeal lithotripsy devices are available to the urologist to effect endoscopic stone fragmentation, including ultrasound, electrohydraulic, and pneumatic units each with its own advantages and limitations [1–3]. At present there are a number of laser systems available for fragmenting urinary calculi (Table 1). As the trend to small caliber semirigid and flexible endoscopes continues, laser lithotriptors seem well suited to the task, particularly in conjunction with ureteroscopy. One such system that has become available for use in intracorporeal lithotripsy is the Alexandrite laser (Dornier). The device we undertook to evaluate is a flashlamp-pumped, Q-switched

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TABLE 1. Comparison of Laser Lithotripters*

Laser	Wavelength	Energy settings	Pulse length	Fiber size
Q switched Nd:YAG	1,064 nm	20–80 mJ	8 ns	400–600 μm
Alexandrite	750 nm	30–80 mJ	150–800 ns	200–300 μm
Holmium:YAG	2,100 nm	200–2000 mJ	300 μsec	200–1000 μm
Pulsed dye				
Candela MDL 3000	504 nm	140 mJ maximum	1.2 μsec	320 μm
Technomed Pulsolith	514 nm	40–200 mJ	2.0 μsec	200–600 μm

*Parameters may vary depending on manufacturer/model.

Alexandrite solid-state laser that operates at a wavelength of 755 nm. This laser operates in a pulsed mode with pulses of 150–800 ns duration delivered at a rate of 1–10 Hz. A variety of energy per pulse settings are also available ranging from 30–80 mJ delivered via a 200-μm-core diameter quartz fiber. A previous ex vivo study has demonstrated the Alexandrite laser to be effective in fragmentation of urinary stones [4]. Herein we report our clinical experience with use of the Alexandrite laser in the treatment of upper urinary tract calculi.

MATERIALS AND METHODS

During a 1-year period, 32 patients underwent an endoscopic stone removal combined with Alexandrite laser lithotripsy. The medical records and relevant radiographs were reviewed and form the basis of this report. A total of 19 male and 13 female patients with a mean age of 52 years (27–80) underwent either retrograde ureteroscopy (30) or percutaneous nephrolithotripsy (2). Ureteral stones were located in the distal (20), mid (6), or proximal (4) ureter, and the average stone size recorded as the maximal diameter was 11 mm (2–27 mm). Ureteroscopic procedures were performed in a standard fashion with a variety of endoscopes, including 6.9, 9.5 and 11.5 F rigid ureteroscopes and 10.5 and 9.8 F flexible actively deflectable ureteroscopes. All calculi in the proximal ureter were approached with flexible instruments, and those in the mid and distal ureter were approached with one of the aforementioned rigid endoscopes. In all instances in which the use of a flexible ureteroscope or rigid instrument of 9.5 F or larger was anticipated, ureteral dilation with a 6 mm 10 cm ureteral balloon dilator was carried out over a guidewire prior to insertion of the ureteroscope. Use of the 6.9F instrument alone was performed alongside a safety guidewire without prior ureteral dilation. Saline irrigation was used in all cases. All patients had an internal ureteral stent placed following ureteroscopy, which was left indwelling for ~ 1 week. In two patients the laser was utilized during percutaneous nephrolithotripsy for staghorn renal calculi. In these instances the major portion of stone debulking was performed with a pneumatic device (Swiss Lithoclast) and the laser was utilized to fragment calyceal stone remnants remote from the nephrostomy tract that were accessed with a flexible nephroscope. All cases were performed under general (30) or spinal (2) anesthesia, and the ureteroscopic cases were performed on an outpatient or 1-day stay basis. The effectiveness of stone fragmentation at the time of the procedure, as well as postoperatively on radiographs, was recorded. Intraoperative or long-term complications related to use of the laser were noted. Stone composition, when available, was recorded as the major component on biochemical analysis.

RESULTS

The fragmentation rate with the Alexandrite laser as the sole modality of lithotripsy was 50% (16/32). In 11 cases, use of the laser had to be abandoned due to equipment malfunction, including fiber burning (5), calibration problems (4), or inability to adequately visualize the helium-neon targeting beam to permit accurate fiber positioning (2). Technical difficulties with the laser such as fiber burning and problems with internal calibrations occurred both early and late in our experience despite attempts by the manufacturer to resolve the deficiencies. In five cases, the laser was ineffective in causing fragmentation of hard stones and use was abandoned. Stone composition in this group showed calcium oxalate monohydrate in 4 and cystine in 1. In all cases of laser failure, conversion to an alternate form of therapy, including simple stone extraction (4), electrohydraulic lithotripsy (8), or the Swiss Lithocast (4), resulted in successful calculus removal or fragmentation. An average energy setting of 60

mJ (30–80 mJ) was utilized and an average of 2,143 pulses per stone were delivered. One patient had an intraoperative complication related to use of the device when a ureteral perforation occurred while the laser was being activated under fluoroscopic control. The patient was managed with an internal stent for 3 weeks and the injury resolved without long-term sequelae. Radiographic follow up was available in 78% (25/32) patients a minimum of 3 months postoperatively. In this group, no long-term urinary tract injury related to use of the laser was noted. Among the cases with stones available for analysis, the composition was as follows: calcium oxalate monohydrate (7), calcium oxalate dihydrate (5), and struvite (2).

DISCUSSION

The use of laser energy as a method of intracorporeal lithotripsy is not a new concept. Mulvaney [5] in 1968 developed a ruby laser that was able to fragment urinary stones. In order to fragment calculi with this device, considerable energy was expended, resulting in excessive heat production. The thermal effects on the surrounding tissue would have resulted in significant tissue injury precluding clinical use of the device. Attempts were subsequently made to use continuous wave CO2 and neodymium:YAG lasers. The inability to transmit CO2 laser energy via nontoxic fibers suitable for endoscopic applications and the thermal effects to adjacent soft tissues associated with the neodymium:YAG devices limited their clinical usefulness as well. Based on the initial experience with these lasers, an understanding of the necessary requirements for successful laser lithotripsy became apparent, including the ability to deliver energy through optical fibers, the need to limit distant thermal effects, and the production of a shock wave of sufficient force to exceed the tensile strength of the stone [6]. In 1986, Watson and Wickham [7] reported on their initial experience with the use of a 504 nm pulsed dye laser to treat ureteric stones. In clinical use, the pulsed dye laser has been found to be safe and effective in treating ureteral calculi. Various authors have reported clinically successful ureteral stone fragmentation in 78–88% of patients treated [8–10]. In an early series using the pulsed dye laser with an 11.5 Fr. rigid ureteroscope, Coptcoat [11] reported a 2% incidence of ureteral stricture and a 7% ureteral perforation rate. More recent experience with the use of the pulsed dye laser in association with smaller calibre ureteroscopes has shown an improved safety margin with laser lithotripsy [12]. Properly used, pulsed dye lasers are now believed to be the safest form of intracorporeal lithotripsy [13]. Since the development of the pulsed dye laser lithotripter, other lasers also have demonstrated their stone fragmenting abilities, including the Q-switched Nd:YAG [14] and the Holmium:YAG laser [15]. Attractive features of the Alexandrite system include its solid-state compact design and lack of toxic materials when compared to the pulsed dye laser.

Several authors have investigated the ex vivo capabilities of Alexandrite laser systems to fragment calculi [4,16]. In a variety of model systems, Alexandrite lasers have effectively fragmented stones of differing composition. Weber and associates [17] conducted in vivo experiments in the pig model exposing the ureter and bladder to Alexandrite laser energy at a variety of settings and examined histologic changes. Hematoma formation could be created in the bladder and ureteral wall and perforations could be produced by direct activation on the urothelium. Chronic studies, however, showed no long-term histologic abnormalities or ureteral strictures. The importance of pulse energy and duration to fiber diameter was emphasized by Strunge and associates [18], who demonstrated interspersion of fiber splinters into the ureteral wall in the pig model. During Alexandrite lithotripsy, pulses $<$ 700 ns duration delivered via a 250 μm fiber resulted in fiber fragmentation or "fiber burning," raising the question of possible ureteral wall injury. By stretching the pulse duration, this fiber destruction is avoided, but absorption at the stone surface becomes more critical. Pertusa and associates [19] did not document fiber splinters using an Alexandrite laser with a delivery system of 320 μm diameter.

Weber et al. [17] reported excellent clinical success fragmenting 26 of 27 calculi using an Alexandrite system with no apparent long-term complications or radiologic followup. In a larger series, Pertusa et al. [20] successfully fragmented 98 of 112 stones and reported no major ureteral wall injuries or fiber destruction. Our assessment of our results as well as our own experience with alternative laser systems and intracorporeal lithotripters led us to conclude that the Alexandrite laser system we tested was inferior to other currently available modalities. It is important to emphasize that some of the inadequacies that we have noted may be addressed in the future by

modifications in the unit and delivery systems. However, publication of our results with the current system is valid and pertinent. Individuals, hospitals, and manufacturers are quick to publish good results. Likewise there is importance in reporting a less favorable experience. Whereas the majority of our failures with the laser were due to technical difficulties with the equipment, which theoretically might be overcome, we also found the unit to be less effective for harder stones, such as those of calcium oxalate monohydrate or cystine composition. A further disadvantage is the single purpose nature of Alexandrite laser devices when compared to alternative laser systems such as the Holmium:YAG, which offers both multipurpose and multispecialty applications. Based on these considerations, we would not recommend this device in its current form for intracorporeal lithotripsy of urinary calculi.

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